# Sawah for Sustainable Rice Farming in Inland Valley Swamps, IVSs, in West Africa[1]

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1. Paper Presented at the Second WAFSRN symposium, Group IV, Irrigated or Inland Valleys Zones, Accra, Ghana, August 28 ~ September 1, 1989.
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## ABSTRACT

Although African rice ( O.Glaberrima ) has been cultivated for thousands of years in West Africa and Asian rice( O. Sativa ) was introduced 13~ 15th century, the Asian type of rice cultivation, 'SAWAH' in Malayo-Indonesian, which means a leveled and bunded rice field, was not prcticed. In contrast, rice is grown on a naturally sloping phreatic and flooding land in most of the Inland Valley Swamps, IVSs, in West Africa.

Most of the soils in IVSs in West Africa are very coarse texture and have low fertility. Mean values were 16% for clay content, 3.54 me/100g for eCEC, 1.36 me/100g for exchangeable Ca, and 1.20 % for total organic carbon content. Extremely poor fertility of soils of IVS in this region may be resulted from prolonged weathering of soils. However the lack of concept and practices of Sawah rice farming is limiting the improvement of water control and accererating the soil deterioration, which prohibits efficient use of fertilizers and high yielding varieties, too.

Since the scale of water flows is relatively small, 10 l/s ~ 1000 l/s, and slope is gentle, 0~ 10 %, in most of the IVSs in this region, it is the best rice ecology to start to introduce Sawah based rice farming system.

On-farm research in benchmark IVSs at Bida, central Nigeria showed that the introduction of Sawah system doubled the rice yield, and at the same time conserved soil and water.

Since the Sawah system is one of the best sustainable rice-based production facilities in the tropical monsoon Asia, and since there are no physical and environmental constraints for developing and managing the Sawah system in most of the IVSs in West Africa, more extensive and intensive research and the On-farm testing are necessary for a wider scale and socioeconomically adaptable introduction of this system.

## 1. INTRODUCTION

Paddy rice culture is at a cradle stage in West Africa. Paddy means here bunded and leveled rice fields for water conservation and control, which is an essential part of the Asian type of rice cultivation.

African rice(O. Glaberrima) has been grown in this region for thousands of years, and Asian rice(O. Sativa) arrived in 13~15th century ( Buddenhagen and Persley, 1978). However, Asian ways of paddy rice culture was introduced only recently, 1960s, by Chinese expert missions. Therefore, most of rice farmers are not familiar to the paddy rice culture yet. Even for rice scientists, ''paddy''does not have a meaning of leveled and bunded rice field , but only a meaning of unhusked rice grain or simply rice, as often seen in the FAO's or WARDA's ( West Africa Rice Development Association) reports.

Since the term of ''paddy'' originates from Malayo-Indonesian term ''padi'', which means rice body or rice grain, in order to avoid confusion, we propose to use Malayo-Indonesian term ''Sawah ''. The term paddy describes rice plant, but the term Sawah describes rice growing environment, with levelling and bunding in various qualities, sizes, shapes, and arrangements.

After the dramatical success of IRRI in Asia, IITA's rice program and WARDA have tried to increase rice yield in this region since 1970. However, there is still a wide yield gap between research institutes' fields and rice farmer's fields:i.e. 4~6 t/ha versus 1 t/ha. Our main objective is how we can fill this gap. In order to fill the gap, (1) research has to be done to know present farmers' growing environment, and (2) research has to be done to improve present poor rice growing environment of local farmers.

During 1983~1989, the authors made several survey trips in West and Central African countries, including Senegal, Guinea, Sierra Leone, Liberia, Cote D'Ivoire, Burkina Faso, Ghana, Togo, Niger, Nigeria, Cameroon and Zaire, to characterize the wetland soils, both at flood plains and in IVSs. During these trips, field conditions of local rice farmers were observed.

On-farm adaptive research to improve farmers' rice growing conditions was done at representative IVSs near Bida, central Nigeria during 1986~1989. Detailed water dynamics and effects of Sawah on rice yields as well as soil conservation were monitored.

## 2.FERTILITY OF INLAND VALLEY AND FLOOD PLAIN SOILS IN WEST AND CENTRAL AFRICA.

### 2.1. Soil Sampling and Analysis.

Selected sampling sites are plotted with major climatic zones on the map of West and Central Africa as shown in Figure 1( Dallard,1982 ). Veldkamp (1979) described the land evaluation of inland valleys in a tropical rain area in Nigeria. Kyuma, Kosaki, and Juo (1986) described the fertility of wetland soils in Nigeria, Cameroon, Sierra Leone and Liberia. This report covers a wider areas and more countries in West and Central Africa as shown in the Figure 1.

Table 1 compares some physico-chemical properties of the soils in IVS and flood plains in various climatic zones of West Africa . Soil pH was measured by glass-electrode with 1:1 of soil to water ratio, organic carbon by Walkley-Black method, total nitrogen by Macro-Kjeldahl method, available phosphorous by Bray No.1 method, exchangeable cations by 1N ammonium acetate extraction followed by atomic absorption/flame photometry methods, exchangeable acidity by 1N KCl extraction followed by alkalimetric titration method , and mechanical analysis by Hydrometer method ( IITA, 1979 ).

### 2.2. Soil Fertility

Soils from flood plains are more fertile than those from IVS.

Exchangeable Ca, Mg, K , eCEC ( effective CEC = Exchangeable cations + exchangeable acidity) and clay content of soils from flood plains is higher than those from IVS. Whereas, sand content of IVS soils is higher than that of flood plains'. The above trends occur in each climatic zone.

There are clear correlations between rainfall regime and soil properties for both IVS and flood plains. The pH, exchangeable Ca, Mg, and Na, and eCEC increase from Equatorial Forest Zone to Semi-arid Sudan and Sahel Savannah Zones. On the other hand, organic carbon, total nitrogen, exchangeable acidity decrease. Available phosphorous ( Bray No.1 method) and exchangeable K have no such relation to the rainfall regime. The coarse sandy texture and the very low fertility of IVS's soils suggest that IVSs in West and Cetral Africa are subjected to excessive leaching of nutrients and loss of clay components from the soils.

Soils from IVSs in Equatorial Forest Zone in Nigeria, especially the south eastern part, i.e. Anambra, Imo, River and Cross river state, show relatively high natural fertility and fine texture (see the last column in the Table 1 ). Nutrient rich sedimentary materials (shales), are the major parent materials of these soils. The dense population of Igbo land in Nigeria relies on these fertile soils. However , fertile soils like these are rather exceptional in Equatorial Forest and Guinea Savannah in West and Central Africa.

kawaguchi K. and Kyuma K.(1977) reported Sawah soil fertility in tropical monsoon Asia. They collected 410 soil samples from nine countries. Mean values were 1.41 % for organic carbon, 0.13% for total nitrogen, 10.0, 0.40 and 18.6 me/100g for exchangeable Ca, K and CEC respectively, and 38% for clay. It is clear the lowland soil fertility from West and central Africa is considerably lower, especially in IVS, than that from tropical monsoon Asia.

## 3. THE RICE HISTORY IN ASIA AND PRESENT CONDITION OF SAWAH / NON-SAWAH FARMING IN INLAND VALLEY SWAMPS IN WEST AFRICA .

### 3.1. Development of Sawah Agriculture in Asia.

Although African rice is said to have originate at flood plains of the Niger river and lake Chad areas a few thousands years ago , West African farmers did not prcticed Sawah based rice production system. On the other hand, Asian rice farmers have selected Asian rice(O. Sativa) some thousand years ago and simultaneously Asian farmers innovated and has been developed Sawah system. In Asia, improvements of rice varieties and rice growing environment occurred together. Therefor, when Asian rice was introduced into West Africa, during 13 ~ 15th century, the traditional African rice was gradually abandoned and tendency of adopting Asian ricein West Africa was accelerated in the last two decades.

Asian rice originated in small inland valley ecology around China, Burma and Laos triangle areas( Watabe T. 1987). Since water flow is small, 100 ~1000 l/s, and there are adequate solpe, 1 ~8%, farmers could develope Sawah to control field water condition. In addition to Sawah, farmers made small sluices prepared with sticks and soils, dug irrigation channels and, if necessary, drainage channels, thus completing the Sawah system. The Sawah system has been improved in size, degree of leveling, and bund quality as well as irrigation-drainage facilities year by year. The Sawah system has been precious properties of farmers and countries which formed backbones of Asian cultures. And Under the on-going improvement of the rice growing environment, farmers effortd to select better varieties might be encouraged.

### 3.2. Why Non-Sawah Rice Farming in West Africa.

Since African rice orriginated in inland delta of Mali, attempts to control water in the huge inland delta like this were far beyond the dreams and technology in this region. African rice has been spreading to the IVS in Guinea, Siera Leone, Liberia and Nigeria. On the other hand, Asian rice arrived first in the mangrove swamp area in this region. Again this ecology refused any attempts to control water because of the huge river water and tidal flow. Although both African and Asian rice spread over IVS which is the best ecology to start Sawah agriculture, West African farmers still went on to the upland and prefer slash and burn upland rice cultivation.

3.3. Present Condition of Inland Valley Rice in West Africa.

IVSs in West Africa are small commonly, 10~500m in width, The amount of water flow is in the order of 100~ 1000 l/s. Therefore, the control of water by construction of Sawah with sluices, small irrigation- drainage lines is not difficult even for local farmers themselves. However, there are few farmers who are growing rice with Sawah system prepared by themselves.

Most of the West African IVS's rice soils which are characterized with very coarse, sandy texture and poor fertility ( Table 1 ) may partly relate to the traditional way of rice farming. We observed clay fraction of topsils are easily subjected to erosion at early growing stage of rice. Because, there are no bund to keep water. Soil surface is bare. There are occasional strong rainfalls. All of these factors contribute flashing clay fractions away from fertile topsoils. Poor sandy soil results in very poor tillering and thus low yield. Situaion described above are common in IVSs in Liberia, Sierra Leone, Guinea, and Nigeria.

There is a wide variety of Sawahs or non-Sawah in IVSs in West and Cetral Africa.

(a), Non-Sawah: Water will flood on and draine from soil surface naturally. There are almost no man-made trials to control water.

(b), Rudimentary Sawah: Bunds are very small, with 10x15cm size , very leaky and incomplete. An individual Sawah is extremely small, that is, mean seize is about 10 $m^2$.

(c), Ridge planting: Some farmers are directly seedling on the ridges prepared from lowland shallow submerged soils.

(d), Small sized Sawah: More advanced farmers are trying to produce primitive dykes made from soil and twigs. Small irrigation channels are sometimes dug, too. Although an individual plot is as small as 10~50$m^2$, bunds are bigger, 20×30cm, and more compacted to protect water leaking than those of primitive Sawah.

All these Sawah are not permanent land preparation. Farmers prepare every year before rice planting and destroy before dry season crops by making big mound or make turn into fallow. Therefore it will be difficult to improve their Sawah year by year.

Similar qualities of the small sized Sawahs are observed by Takaya et al. (1981) at the north western part of Sumatra island, which are prepared by sifting cultivators.

## 4. ON-FARM RESEARCH FOR INTRODUCTION OF SAWAH FARMING IN INLAND VALLEY SWAMPS IN CENTRAL NIGERIA.

On-Farm researchs for introduction of Sawah-based farming were initiated in 1986 in two IVS, Gara and Anfani, near Bida, central Nigeria ( Figure 2). In 1987, an additional IVS , Gadza, was included in the study ( Figure 2).

Studies consist of (1) physical characterization of IVS in study sites, (2) field monitoring of water balance and land use pattern, and (3) evaluation of the effects of Sawah farming system on rice yields and on soil conservation.

4.1. Hydrological Studies.

Table 2 shows composition and distribution of each catchment. Gara and Anfani may be classified as stream flow valley, whereas Gadza as river overflow valley (Savvides 1981). The bottom land are almost flat, 1~2% of slope, and 20~80m width in Gara and Anfani, 100~400m in Gadza. The valley fringe has the same width as bottom land. But slope is slightly steep, 2~8%.

Figure 3 shows distribution of rice field between fringe and bottom land in Gara at November 1986. Quality of the rice field can be described as primitive or rudimentary Sawah: irregular in shape and arrangement, small plot size, 3~30m², with weak and leaky bund or no bunds and uneven surface with poor or no leveling. Rice field, horizontally lined area, distributes mainly in valley bottom ; 7ha at Gara, 11ha at Anfani, 100ha at Gadza, which cover 65~75% of total areas of valley bottoms respoectively. Rice fiels in the valley fringe has only 7~9% of valley fringe in the three benchimark IVSs.

Figure 4 shows monthly rainfall-water discharge relationship in Gara valley during March 1986 to November 1988. Water discharge has been measured at the center of the Transect XIII ( see, Figure 3 ), using triangular broad crested weir with an internal angle of 150° ( IITA Annual report, 1986). Water discharge data are expressed as mm/month per total catchment area of 800 ha.

Gara had average rainfall in 1986, near to the lowest in 1987, and higher than average in 1988. In 1986, rainfall started in March and stopped at the end of October. However, water flow in the central stream started only late July and even continued until the end of February of next year. As shown in the figure 4, the rice cultivation practices are rather correlated to the water discharge pattern than to the rainfall. Although the water discharge is only 13% of the total rainfall precipitated at 800ha, the water accumulate to the valley bottom. Since the area of the valley bottom is only 10 ha ( table 2), valley bottom received actually, at least, 11520mm ( = 144mm x 800/10 ) of equivalent water. This means that rice fields in bottom land of Gara valley will get enough, maybe too much in bigger IVS such as Gadza, water for rice cultivation. If we include fringe parts for the calculation, the equivalent water discharge becomes 2560mm, which suggests that expanding rice fields to the fringe is risky because of shortage of water. This is confimed by direct field monitoring of water conditions as described below.

Evevn in the drought year such as 1987, and even in the drought prone IVS such as Gara, IVS had recieved enough water for rice, at least in the bottom land. This shows high potential to increase rice production by improving water management practice by introducing the Sawah system. This data deny the conclusion of Gunneweg (1986): the production of lowland paddy rice in the Bida area is risky and hydromorphic rainfed rice is probably a more acceptable crop. High potential for lowland rice production by Sawah system in IVSs around Bida area is further clear by comparing the Figures 5, 6, and 7.

4.2. Field Monitoring of Water Balance

Direct monitoring of ground and surface water levels and land use patterns of the three IVSs were initiated since July 1986 in Gara and Anfani, and in Gadza since June 1987. Thirteen transect lines in Gara, 10 in Anfani, and 7 in Gadza were monitored every two weeks. Each transect has 5 to 18 ground and surface water measuring plastic tubes, 2.5 inches of diameter and 2m length. Bottom part of the tubes was installed at 1.5 m depth in soil and the top part at 0.5 m above ground level. Some examples of fluctuation of ground and surface water depth in cm at Gara and Gadza are shown in Figures 5,6, and 7, respectively. Each figure has a cross section of topography along the transect line. Land use patterns are superimposed in the contour lines of ground water depth.

Figure 5 shows the relation between rainfall pattern and ground water dynamics along the transect VIII in Gara Valley, the driest part of drought prone IVS. In 1987, August had the highest rainfall. Major flooding, which is defined as the flooding that covers more than 50% bottom land area started at the end of August, whereas in 1986, major flooding started at the end of September. Farmers started planting rice earlier in 1987 than in 1986. Major flooding continued until December 3, whereas in 1987 it stopped at November 9. Total length of the major flooding period was similar in 1986 ( 76 days) and 1987 ( 77 days). Thus this transect has drought prone water balance based on the classification in the Table 3.

The mean of the thirteen transects in the Gara were 102 days in 1986, whereas it was 93 days in 1987. These results are well correlated to the amount of annual rainfall of 1085 mm in 1986 and 870 mm in 1987. The amount of rainfall in 1987 was near the lowest record in Bida. Rice field in the valley fringe suffered continuous shortage of water and the rice crop succumbed to drought stress.

Although fringe part suffered severe drought stress at 1986 and 1987, bottom land did not have severe water stress. In 1988 of high rainfall year, most of the rice field could received enough water for grow rice well, except for only rice field at the highest position in the fringe part.

Figure 6 shows typical transect in Gadza, favorable IVS. Most of the rice field never suffered drought stress even in 1987 of drought year. In 1987, only some part of rice field at the fringe might suffered water stress. In 1988 of average rainfall, all of the rice field recieved enough water for lowland rice. The most part of the transect maintained flooding longer than 150 days in both 1987 and 1988. After rice, IVS soils keep enough residual moisture which make possible to grow wide range of dry season crops intensively, such as cassava, okro, egg plant, pepper, as shown in the Figures 5, 6, and 7. Small portion of drought prone part along the river, where has similar physiographic character to natural levee, although very small scale, are used for sugar cane.

Figure 7 shows transect 5 which has IITA's researcher managed trials. All the improved Sawah from I~V had no problems about water stress for rice in 1987 and 1988.

Based on the dynamics of the ground and surface water, the balances of water in rice field are calculated ( Table 3 ). The data show number of days with a continuous flooding in fields at Gara and Anfani valleys during July 1986 to June 1987, and May 1987 to December 1988 for Gadza.

Tentatively three categories of water balances are distinguished (Table 3). They are fields with (a) continuous flooding for more than 150 days, which is classified as favourable, (b) a continuous flooding of 100 to 150 days, which is classified as intermediate, and (c) a continuous flooding of less than 100 days, which is classified as drought prone. The implications of these field types are that a long duration rice variety can be grown in field type (a) ,a short to middle-season variety is suitable for field type (b), and rice cultivation is risky without technology to keep water such Sawah and shorter season varieties is necessary for field type (c). Also for field types (a) and (b) residual moisture is sufficient to grow dry season crops.

Most of the rice fields in the valley bottom maintain water balance belong to the Intermediate, whereas water balances of rice field on fringe have the drought prone in Gara and Anfani, whereas Gadza has favourable water balnace in bottom land and intermediate to drought prone water balance in the fringe, as shown in the Table 5.

4.3. On-Farm Research on Improved Sawah System.

In 1986~1987 at Gara and in 1987 ~ 1988 at Gadza, a small scale Sawah improvement trial was conducted. Farmers' rice fields were improved to make a Sawah resulting in regular shape and bigger plot size, compacted and made bund bigger to protect leakage of water, and levelled with smooth surface.

In farmer's over-drained rice fields, water requirement has been found to be quite high ( 71~240mm/day) in even relatively advanced levels of Sawah, thus resulting in very low fertilizer use efficiency. In relatively improved Sawah in Gara valley, water requirement is much lower, i.e. 21~71 mm/day. Also sawah in the valley bottoms have an estimated optimum water requirement of 15~40 mm/day. However those in valley fringe where considerable leakage occurs because of sandy texture and low ground water table have higher water requirement ( IITA annual report ,1986).

Table 4 shows that yield of rice varieties doubles with improved field conditions by construction of Sawah. Farmers' local variety in the Table 4 was identified as FARO 17 or related improved variety. Also, the response to higher rates of fertilizer use is nearly twice as much in the improved sawah field as in local farmers' field conditions. These results are confirmed under farmers' field conditions and management levels as shown in Table 5( Ashraf et al.1988 ). An yield increase of at least 100% is obtained on the field where farmers are able to maintain a water and moisture levels for at least 50% of the crop duration ( Palada et.al,1987). Most of rice fields which have water duration more than 50% are located at valley bottom, on the other hand rice fiels with less than 50% are located at valley fringe.

Table 6 shows the rice yields of various varieties in the improved Sawah along the toposequence in Gadza valley during August 1987 ~January 1988. Fertilizer levels are 90KgN/ha, 60Kg$P_2O_5$/ha, and 30Kg$K_2O$/ha. Table 7 shows topsoil fertility of the toposequence. Since as shown in the Figure 7, all of the improved Sawah had enough water for rice growing, yield differeces between I~V Sawahs may come from soil fertility. Although soil fertility shows strong effect on rice yield, the improvement of Sawah made rice yield more than double irrespective with the soil fertility.

Since most of the operation was done using traditional hand tools, the quality of bund and degree of levelling were not excellent. With subsequent cropping it is expected that the quality of bund and levelling will improve, provided farmers do not destroy the established bunds.

### 4.4. Effects of Improved Sawah System on Soil Fertility and Conservation for Sustainable Rice-Based Farming in West Africa.

Table 8 shows the physico-chemical properties of rice soils at transect 7 (Figure3) in Gara. Valley fringe soils are low in clay and effective CEC and has low in chemical fertility, and have sandy and very poor subsoils. Some parts of the valley bottoms in Gara and also in Anfani and Gadza have very thin layer of top soil, and there are some wasted lands that have no clay layer anymore. Most of the inland valleys in this area are now considered as highly degraded soils due to erosion and leaching of nutrients.

Table 9 shows the dynamics of the physico-chemical properties of rice soils in improved Sawah and in farmers' rice fields at the IVS in Gara. The properties of the top 5 cm soils before rice cultivation was compared to the one after rice cultivation. Top soils in the improved Sawah seemed to accumulate clay during rice growing period which results in higher effective CEC and exchangeable calcium and magnesium. In farmers' field there was no clear tendency of increasing clay content. In fact, soils in farmers' rice fields have a tendency to decrease silt and clay fractions. Water in an improved Sawah was hold for 1 to 2 days at fringe and 3 to 5 days at bottom land, while in farmers' field it was estimated at few hours only. Accordingly, clay particles in water in the improved Sawah have enough time for sedimentation on the top of submerged soils. Whereas, soils in farmers' rice field were easily exposed to erosion by continuous flow and occasional sudden strong flash of suface water.

To confirm the effect of Sawah for soil conservation by depositing clay fraction, however, it may be necessary to monitor the soil properties of both farmers' rice field and of Sawah for more prolonged years.

Sawah systems have been recognized as one of the best sustainable production systems in the wide range of climatic conditions, i.e. from temperate monsoon to humid/subhumid tropics in Asia. There are no physical and environmental limitations to develop and manage Sawah system in most of West and Central African IVS as observed by our field trips and as demonstrated by the pioneer works of the Chinese teams. Hence, more intensive research and On-farm testings are necessary for wider scale introduction or technology transfer of this system.

## AKNOWLEDGEMENT

We wish to express our most sincere gratitude to the following people who helpted us during our field surveys in West and Central African countries.

Dr. T. A. Okusami and Mr. G. O.Oyediran : Obafemi Awolowo University. Dr. A. Fagbami : University of Ibadan, Nigeria. Mr. E. Shiawoya : NSADP, Bida, Nigeria. Dr. B. Wudiri: NCRI, Bida, Nigeria. Mr. Idi Mohammed:Gashua, Nigeria. Dr. J. A. Ayuk-Takem, IRA,Yaounde Cameroun. Dr. A.C. Roy:NCRE, Dschang,Cameroun. Mr. Sawadogo Jules Aine: CERCI, Bobodioulasso, Burkinafaso. Mr. Gome Jean:CERCI, Banfora, Burkinafaso. Mr.S.Diatta, WARDA, Bouake, Cote D'Ivoire. Mr. Idi Mamane: ONAHA,, Niamey, Niger. Mr. Kikinoi N'kum: PNR, Kikwit, Zaire. Mr. P. Agyili, Mr. Edward D. Dennis, Mr. R. d. Asiamah, and Mr. Roland Nuhu Issaka: Soil Research Institute, Kumasi, Ghana. Mr. Knperminc Oliver: IRAT, Nyankpara, Ghana. Mr.H. Van Brandt and Mr. H. Diara and Mr. W. Godderis: Regional Irrigated Rice Research Station, WARDA, St. Luis, Senegal. Mr. R.Rondeau and Mr. D. Dureau : Projet Agricole de Gueckedou (PAG), Guinee. Mr. A. Toure, Mr. A. Sandio Diallo and Mr. M. Sidibe: Centre de Recherche Agronomique de Kilissi,BP 163, Kindia, Rep.de Guinee. Mr. A. S. Diallo, Mr. S. Sounonnonbah, Mr. Baldeh and Mr. D. Souare: Director of Research, Chief of Division Programation et Controle des Programmes, Extension officer and Agronomist,respectively, de la Ministry of Rural Development at the office of Direction Nationale Recherches Agronomiques, Conakry, Guinee. Dr. M. Agyen-Sampong and Mr. C. Dixon, Regional Mangrove Swamp Rice Research Station, Rokupr, Sierra Leone. Mr. Gordon,Director of LWDD/MANR, and Mr. Jalloh

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Table 1. Some physico-chemical characteristics of surface- and sub-soils of IVS and Flood plains in West Africa and Central Africa.

| Site | & Climate | pH | Org. C (%) | Total N (%) | Bray No.1P (ppm) | Exchangeable Cations( me/100g) Ca | Mg | K | Na | Acidity | eCEC[9] | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flood Plain | Humid[1] n=41[4] SD[5]= | 4.59 ± 0.32 | 1.96 ± 3.0 | 0.207 ± 0.19 | 4.3 ± 6.1 | 1.74 ± 1.9 | 1.40 ± 1.6 | 0.36 ± 0.29 | 0.10 ± 0.07 | 3.32 ± 2.04 | 6.85 ± 2.7 | 30 ± 17 | 37 ± 17 | 33 ± 14 |
| | Sub.H[2] n=17[4] SD[5]= | 5.88 ± 0.81 | 0.52 ± 0.38 | 0.075 ± 0.03 | 2.8 ± 3.3 | 5.92 ± 3.5 | 2.39 ± 1.4 | 0.24 ± 0.08 | 0.53 ± 0.77 | 0.28 ± 0.30 | 9.36 ± 5.2 | 47 ± 20 | 28 ± 10 | 25 ± 13 |
| | SemiA[3] n=30[4] SD[5]= | 5.69 ± 1.02 | 0.63 ± 0.64 | 0.075 ± 0.06 | 1.7 ± 1.5 | 7.64 ± 7.8 | 4.28 ± 1.95 | 0.57 ± 0.49 | 2.39 ± 3.12 | 0.29 ± 0.51 | 15.27 ± 8.3 | 52 ± 16 | 18 ± 10 | 30 ± 14 |
| IVS[6] | Humid[7] n=56[4] SD[5]= | 4.82 ± 0.34 | 1.62 ± 2.2 | 0.159 ± 0.16 | 3.6 ± 3.9 | 0.62 ± 0.62 | 0.31 ± 0.43 | 0.13 ± 0.14 | 0.09 ± 0.08 | 1.72 ± 0.93 | 2.89 ± 1.38 | 65 ± 19 | 18 ± 12 | 17 ± 15 |
| | Sub.H[2] n=39[4] SD[5]= | 5.05 ± 0.60 | 0.74 ± 0.86 | 0.079 ± 0.08 | 3.3 ± 3.8 | 1.47 ± 1.42 | 0.79 ± 0.88 | 0.18 ± 0.18 | 0.17 ± 0.22 | 0.84 ± 0.67 | 3.50 ± 2.64 | 61 ± 18 | 24 ± 11 | 15 ± 15 |
| | SemiA[3] n=8[4] SD[5]= | 6.70 ± 0.92 | 0.51 ± 0.22 | 0.073 ± 0.03 | 3.8 ± 4.1 | 5.94 ± 3.21 | 1.41 ± 0.55 | 0.14 ± 0.07 | 0.60 ± 0.61 | 0.13 ± 0.08 | 8.23 ± 4.01 | 56 ± 16 | 29 ± 12 | 15 ± 6 |
| IVS | Humid[8] n=22[4] SD[5]= | 4.90 ± 0.81 | 1.38 ± 1.28 | 0.185 ± 0.13 | 7.5 ± 12.5 | 8.35 ± 9.3 | 2.61 ± 2.29 | 0.33 ± 0.32 | 0.10 ± 0.07 | 1.80 ± 2.38 | 12.82 ± 10.45 | 49 ± 22 | 25 ± 13 | 26 ± 16 |

[1]:Humid climate. Equatorial Forest Zone. [2]:Subhumid climate. Guinea Savannah Zone. [3]:Semi-arid climate. Sudan or Sahel Savannah Zones. [4]:Number of soil samples analysed. [5]:Standard deviation. [6]: Inland valley swamps. [7]:Collected from IVSs in Equatorial Forest Zone except for Nigeria. [8]:Collected from IVSs in Equatorial Forest Zone in Nigeria. [9]:effective CEC = exchangeable cations + exchageable acidity.

Table 2. Composition and rice field distribution of the three benchmark IVSs, Gara , Anfani Valleys( surveyed in November 1986) and Gadza ( 1987).

| | Gara | Anfani | Gadza |
|---|---|---|---|
| Total catchment area(ha) | 800 | 1300 | 6000 |
| Upland area(ha) | 755 | 1250 | 4450 |
| Fringe area(ha) | 35 | 35 | 400 |
| Valley botoom area(ha) | 10 | 15 | 150 |
| Fringe rice field(ha) | 3 | 3 | 30 |
| Valley bottom rice field(ha) | 7 | 11 | 100 |

Table 3. Classification of Water Balances of Fields by Number of Days with a Continuous Flooding in Fields. Examples at Gara and Anfani During July 1986~June 1987, and Gadza During May 1987~December 1988.

| Classification | No.of days of continuous flooding | Gara | | Anfani | | Gadza | |
|---|---|---|---|---|---|---|---|
| | | Bottom | Fringe | Bottom | Fringe | Bottom | Fringe |
| Favourable | > 150 | 0 ha | 0 ha | 0 ha | 0 ha | 65 ha | 0 ha |
| Intermediate | 100~150 | 6 ha | 1 ha | 7 ha | 0.3ha | 30 ha | 10 ha |
| Drought prone | < 100 | 1 ha | 2 ha | 4 ha | 2.7ha | 5 ha | 20 ha |

Table 4. Effect of Sawah System and Fertilizer Rate on Rice Yield (t/ha) of Inland Valley of Gara, Bida, Nigeria, 1986~87( IITA Annual report, 1986)

| Rice Variety | Fertilizer rate (kg/ha)[1] | Farmers' field & managements[2] | Improved Sawah & farmers' Mgt.[2] | Improved Sawah & Researcher Mgt.[2] |
|---|---|---|---|---|
| Local | 15-15-15 | 1.7 | 3.6 | 4.7 |
| | 90-60-60 | 2.4 | 3.3 | 6.2 |
| ITA 212 | 15-15-15 | 2.2 | 3.2 | 4.4 |
| | 90-60-60 | 3.5 | 4.6 | 4.7 |
| ITA 306 | 15-15-15 | 1.8 | 4.9 | 4.6 |
| | 90-60-60 | 3.0 | 6.8 | 6.1 |
| FARO 29 | 15-15-15 | 1.7 | 3.1 | 4.6 |
| | 90-60-60 | 2.2 | 6.1 | 5.3 |
| Mean | 15-15-15 | 1.9 ± 0.2 | 3.7 ± 0.9 | 4.6 ± 0.1 |
| | 90-60-60 | 2.8 ± 0.6 | 5.2 ± 1.6 | 5.6 ± 0.7 |

[1]: Refers to N, $P_2O_5$, and $K_2O$ respectively.
[2]: Farmers' field refers to ,more or less, natural slope and poor water control conditions, and Improved Sawah refers to levelled and bunded field with relatively good water control.
[3]: The local variety was identified as FARO 17 or related variety.

Table 5. Yield Response of Rice Varieties to Field Water Duration in Small Inland Valleys, Farmer-managed Trials, Nigeria 1986/87.

| Variety | RICE FIELD WATER DURATION[1] Less than 50% Low F[2] | Less than 50% High F[2] | More than 50% Low F[2] | More than 50% High F[2] |
|---|---|---|---|---|
| | | ( Yield, t/ha) | | |
| ITA 306 | 1.82 | 2.32 | 2.55 | 3.58 |
| FARO 29 | 1.04 | 1.39 | 2.43 | 3.32 |
| ITA 212 | 1.04 | 1.79 | 2.12 | 3.27 |
| ITA 249 | 0.25 | 0.28 | 1.44 | 1.84 |
| Local | 1.20 | 1.48 | 1.86 | 2.65 |
| Fertilizer mean | 1.07 | 1.45 | 2.08 | 2.93 |
| Water duration mean | 1.26 | | 2.51 | |

LSD(1%) for comparing means between water duration = 0.67t, C.V.= 12.1%
[1]:Fields under water saturation or over saturation( flooded )for a period of less or more than half the growth duration.
[2]:Low F = 15 Kg N, 15 Kg $P_2O_5$, and 15 kg $K_2O$ / ha.
High F = 90 Kg N, 60 Kg $P_2O_5$, and 30 Kg $K_2O$ / ha.
Source: IITA Annual Report. 1987.

Table 6. Rice yields of various varieties in the improved SAWAH in toposequence along the transect V in Gadza valley, August 1987 ~ January 1988.

| Entry designation | yields (ton/ha) at a various toposequence Fring-I | II | III | IV | V-Bottom | Mean |
|---|---|---|---|---|---|---|
| ITA230 | 4.7 | 3.6 | 5.7 | 6.4 | 7.6 | 5.6 |
| ITA306 | 4.9 | 4.1 | 4.3 | 6.6 | 7.5 | 5.4 |
| ITA312 | 3.0 | 5.5 | 5.3 | 6.9 | 6.9 | 5.5 |
| Tox3109-75-4-1 | 3.3 | 4.2 | 5.4 | 6.2 | 5.6 | 4.9 |
| Tox3114-10-1-1 | 2.6 | 3.8 | 2.8 | 4.7 | 4.5 | 3.7 |
| Tox3118-2-E2-2 | 5.0 | 5.0 | 5.5 | 11.2? | 6.6 | 6.7 |
| Tox3118-6-E2-3 | 3.3 | 6.3 | 4.7 | 7.6 | 7.1 | 5.8 |
| Tox3118-47-1-1 | 3.0 | 5.3 | 5.2 | 5.8 | 6.0 | 5.1 |
| Tox3118-78-2-1 | 3.0 | 6.4 | 5.6 | 5.6 | 6.5 | 5.4 |
| Tox3133-56-1-3 | 2.1 | 5.3 | 3.4 | 6.7 | 6.2 | 4.7 |
| ITA308 | 2.7 | 5.9 | 6.9 | 4.8 | 5.0 | 5.1 |
| Manbeshi(local check) | 2.1 | 4.9 | 4.3 | 4.8 | 6.2 | 4.5 |
| Mean | 3.3 | 5.0 | 4.9 | 6.4 | 6.3 | 5.1 |

Table 7, Top 10cm Soil Characteristics of Toposequence Trials at Gadza IVS. Sampled at September ,1987, just before transplanting of rice.

| Topo-sequence | pH | Org-C (%) | Total N (%) | Bray 1-P ppm | Exchangeable Catins Ca | Mg | Mn | K | Na | Total Acidity | effective CEC | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (me / 100g soil) | | | | | | | | | |
| I , Fringe | 5.5 | 0.17 | 0.015 | 0.9 | 0.47 | 0.16 | 0.01 | 0.06 | 0.09 | 0.220 | 1.01 | 94 | 4 | 3 |
| II | 5.5 | 0.54 | 0.046 | 4.8 | 0.86 | 0.27 | 0.04 | 0.09 | 0.12 | 0.190 | 1.57 | 81 | 14 | 5 |
| III | 5.1 | 1.16 | 0.066 | 1.2 | 1.27 | 0.46 | 0.07 | 0.14 | 0.01 | 0.257 | 2.21 | 66 | 28 | 7 |
| IV | 5.0 | 0.93 | 0.068 | 1.1 | 1.02 | 0.41 | 0.06 | 0.10 | 0.13 | 0.270 | 1.99 | 72 | 12 | 17 |
| V, Bottom | 5.0 | 0.72 | 0.056 | 1.2 | 1.13 | 0.43 | 0.06 | 0.10 | 0.11 | 0.257 | 2.09 | 72 | 12 | 17 |

Table 8. Selected Physico-Chemical Characteristics of Rice Soils in Toposequence at Transect 7 in Gara, sampled on January 15, 1987, harvesting Time.

| Selected Properties | Depth (cm) | Toposequence I Fringe Upper | Toposequence I Fringe Lower | Toposequence I Valley Bottom 1 | Toposequence I Valley Bottom 2 | Toposequence II Fringe Upper | Toposequence II Fringe Lower | Toposequence II Valley Bottom 1 | Toposequence II Valley Bottom 2 |
|---|---|---|---|---|---|---|---|---|---|
| Clay(%) | 0-5 | 6 | 8 | 16 | 21 | 8 | 12 | 16 | 22 |
| | 10-20 | 6 | 8 | 16 | 21 | 8 | 10 | 20 | 20 |
| | 20-30 | 6 | 9 | 24 | 10 | 6 | 8 | 25 | 10 |
| | 40-50 | 5 | 6 | 6 | 8 | 6 | 7 | 9 | 10 |
| eCEC (me/100g) | 0-5 | 1.3 | 1.6 | 3.1 | 3.8 | 1.4 | 1.8 | 3.3 | 3.8 |
| | 10-20 | 0.9 | 1.3 | 3.5 | 3.8 | 1.4 | 1.8 | 3.3 | 3.8 |
| | 20-30 | 0.8 | 1.0 | 4.3 | 1.7 | 0.6 | 1.2 | 4.4 | 1.6 |
| | 40-50 | 0.6 | 0.9 | 0.8 | 0.8 | 0.6 | 0.8 | 1.4 | 2.0 |
| Exchangeable Ca (me/100g) | 0-5 | 0.81 | 0.86 | 1.65 | 1.87 | 0.83 | 0.77 | 1.56 | 1.56 |
| | 10-20 | 0.37 | 0.64 | 1.11 | 1.50 | 0.60 | 0.44 | 1.10 | 1.26 |
| | 20-30 | 0.43 | 0.56 | 0.83 | 0.58 | 0.36 | 0.33 | 1.69 | 0.47 |
| | 40-50 | 0.36 | 0.48 | 0.33 | 0.36 | 0.36 | 0.22 | 0.42 | 0.40 |
| Exchangeable K (me/100g) | 0-5 | 0.10 | 0.07 | 0.11 | 0.11 | 0.08 | 0.08 | 0.23 | 0.23 |
| | 10-20 | 0.04 | 0.05 | 0.09 | 0.08 | 0.09 | 0.05 | 0.08 | 0.12 |
| | 20-30 | 0.04 | 0.03 | 0.07 | 0.04 | 0.04 | 0.05 | 0.08 | 0.06 |
| | 40-50 | 0.03 | 0.03 | 0.04 | 0.03 | 0.06 | 0.04 | 0.04 | 0.08 |

Table 9. Dynamics of Physico-Chemical Natures of Rice Soils in Improved Sawah and in Farmers' Field at Inland Valley, Gara.

| Soil | No. | pH | Org. C (%) | Total N (%) | Exchangeable Cations(me/100g) Ca | Mg | K | Na | Acidity | eCEC | Avail.P Bray 1 (ppm) | Sand (%) | Silt (%) | Clay (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I.Topsoil, 0~5cm, sampled on September 19, 1986, transplanting time. | | | | | | | | | | | | | | |
| Impro-ved Sawah | 1 | 5.1 | 0.42 | 0.026 | 0.53 | 0.11 | 0.08 | 0.01 | 0.34 | 1.12 | 23.2 | 82 | 11 | 7 |
| | 2 | 5.6 | 1.50 | 0.108 | 1.32 | 0.29 | 0.19 | 0.01 | 1.23 | 3.17 | 13.5 | 63 | 20 | 17 |
| | 3 | 4.4 | 1.41 | 0.104 | 1.37 | 0.31 | 0.21 | 0.03 | 1.00 | 3.08 | 10.9 | 66 | 17 | 17 |
| | 4 | 5.2 | 0.49 | 0.050 | 0.64 | 0.12 | 0.17 | 0.03 | 0.33 | 1.34 | 53.2 | 82 | 8 | 10 |
| | 5 | 4.8 | 1.43 | 0.110 | 1.44 | 0.33 | 0.29 | 0.03 | 0.95 | 3.18 | 14.9 | 64 | 19 | 17 |
| | 6 | 4.7 | 1.84 | 0.136 | 2.25 | 0.43 | 0.39 | 0.05 | 0.81 | 4.15 | 9.1 | 55 | 23 | 22 |
| Far-mers' Rice Field | 1 | 5.3 | 0.87 | 0.034 | 0.52 | 0.19 | 0.11 | 0.02 | 0.52 | 1.44 | 17.2 | 78 | 14 | 8 |
| | 2 | 5.0 | 1.26 | 0.076 | 0.80 | 0.17 | 0.13 | 0.02 | 1.24 | 2.47 | 9.0 | 68 | 20 | 12 |
| | 3 | 4.9 | 1.19 | 0.088 | 0.82 | 0.20 | 0.14 | 0.02 | 1.48 | 2.77 | 5.9 | 62 | 20 | 18 |
| | 4 | 5.1 | 2.69 | 0.200 | 2.10 | 0.44 | 0.46 | 0.07 | 1.04 | 4.27 | 11.2 | 52 | 26 | 22 |
| II. Topsoil, 0~5cm, sampled on January 15, 1987, harvesting time. Figures are difference between I and II: harvesting-transplanting. | | | | | | | | | | | | | | |
| Impro-ved Sawah | 1 | 0.2 | 0.41 | -0.004 | 0.31 | 0.13 | 0.01 | 0.10 | -0.14 | 0.37 | -16.6 | 0 | 0 | 0 |
| | 2 | -0.1 | 0.04 | 0.021 | 0.33 | 0.13 | -0.08 | 0.08 | -0.25 | 0.18 | -6.9 | 1 | 0 | -1 |
| | 3 | -0.4 | -0.04 | 0.008 | 0.50 | 0.50 | -0.10 | 0.07 | -0.14 | 0.69 | -3.7 | -11 | 7 | 4 |
| | 4 | -0.3 | 0.07 | 0.009 | 0.33 | 0.21 | -0.08 | 0.07 | -0.11 | 0.87 | -23.6 | -10 | 8 | 2 |
| | 5 | -0.2 | -0.05 | -0.004 | 1.06 | 0.17 | -0.14 | 0.09 | 0.02 | 1.12 | -7.4 | 1 | -6 | 5 |
| | 6 | -0.2 | -0.15 | 0.019 | 0.07 | 0.15 | -0.18 | 0.11 | 0.82 | 0.89 | -3.9 | -7 | 2 | 5 |
| Far-mers' Rice Field | 1 | 0.0 | -0.41 | 0.000 | 0.31 | 0.09 | -0.03 | 0.09 | -0.52 | -0.09 | -14.2 | 6 | -6 | 0 |
| | 2 | 0.0 | -0.29 | -0.107 | -0.03 | 0.08 | -0.05 | 0.09 | -0.66 | -0.63 | -7.6 | 5 | -5 | 0 |
| | 3 | -0.1 | 0.24 | 0.014 | 0.74 | 0.28 | 0.09 | 0.13 | -0.74 | -0.51 | -3.2 | 2 | 0 | -2 |
| | 4 | -0.8 | -1.51 | -0.110 | -0.54 | 0.01 | -0.23 | 0.05 | 0.34 | -0.46 | -5.8 | 11 | -11 | 0 |

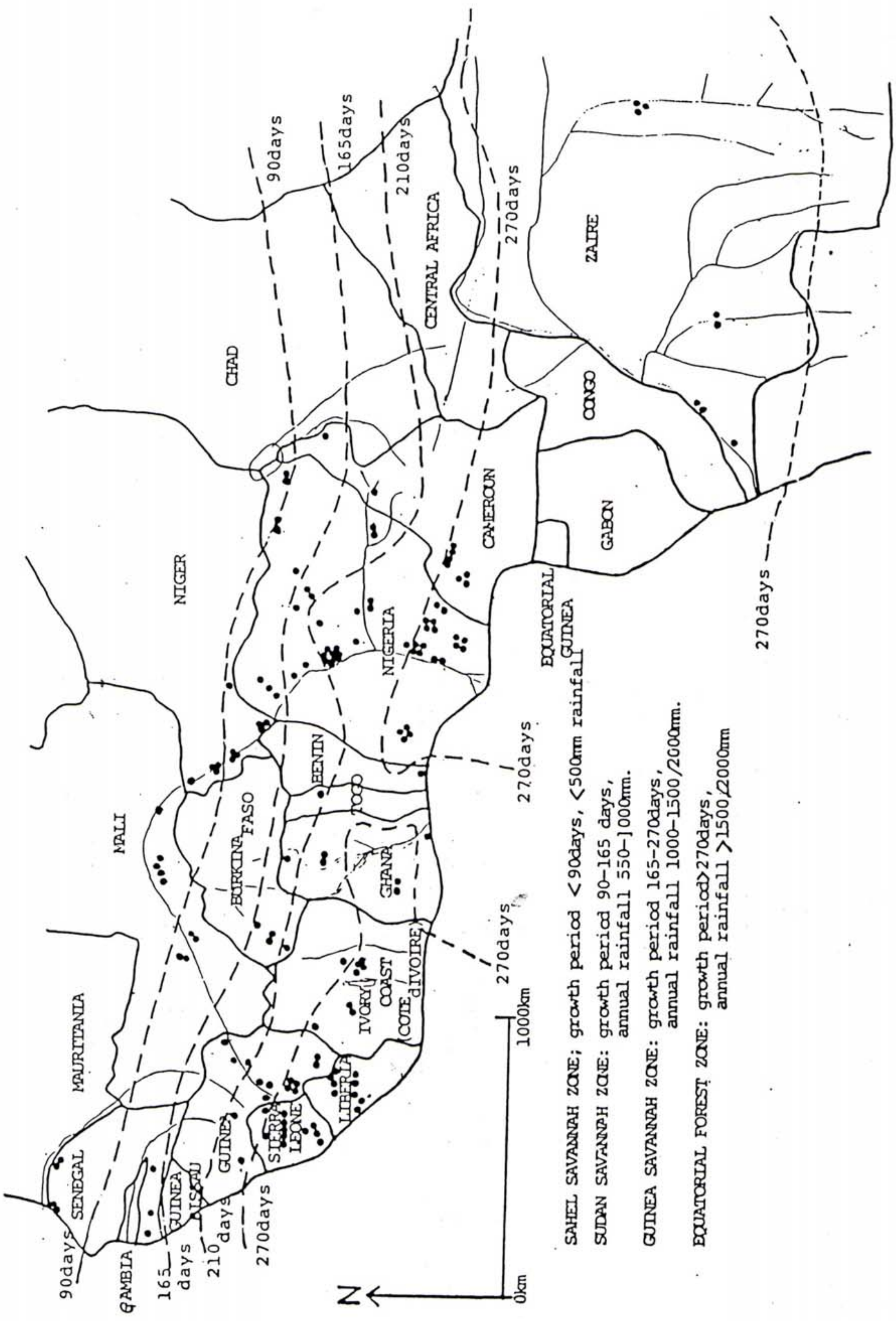


Figure 1. Selected Sampling Siets Dotted on the Map of West and Central Africa. Major Climatic Zones are Shown by Broken Lines.

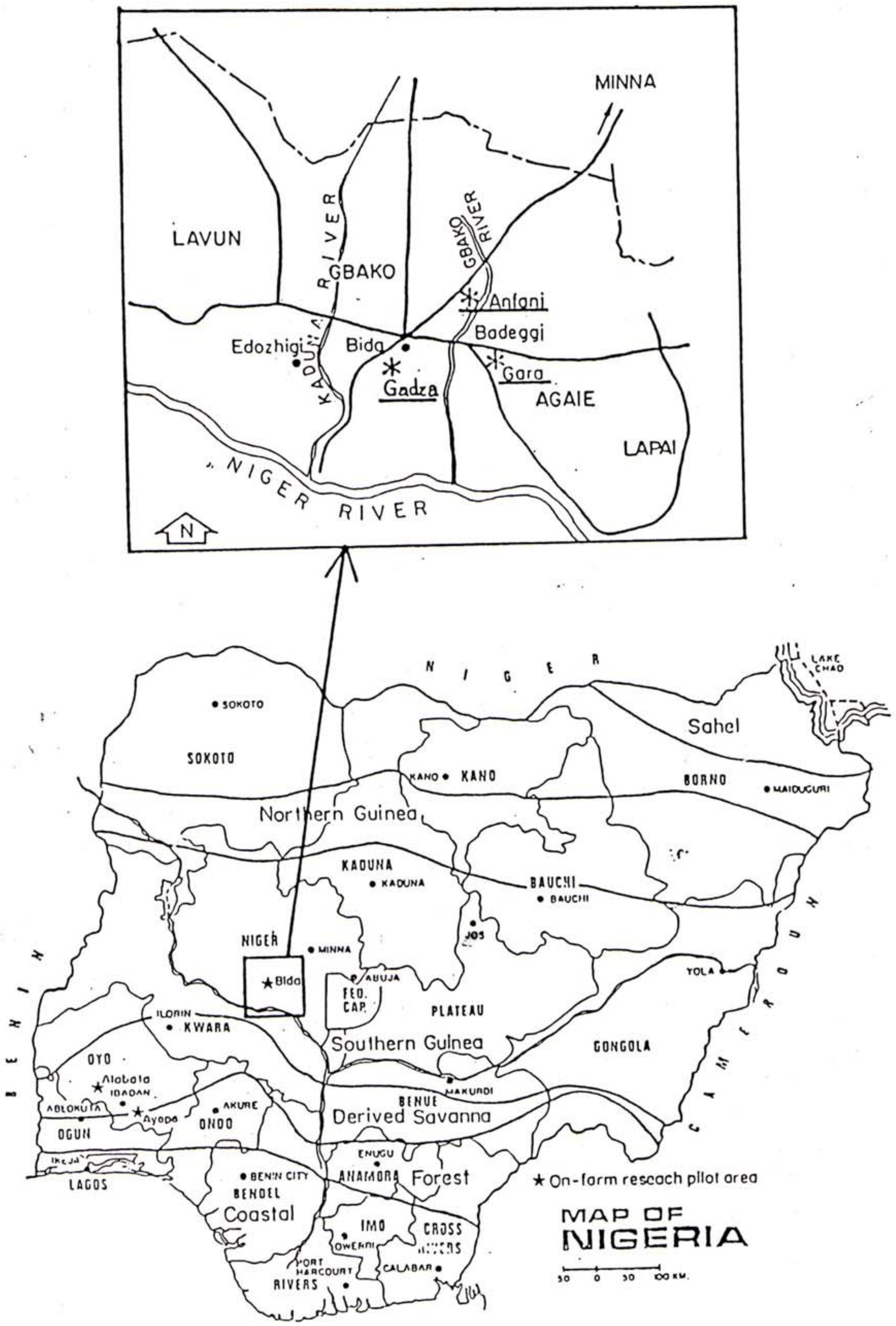


Figure 2. Map of Nigeria and Bida Area, Central Nigeria,Showing Three Benchmark Inland Valley Swamps of Anfani, Gadza, and Gara.

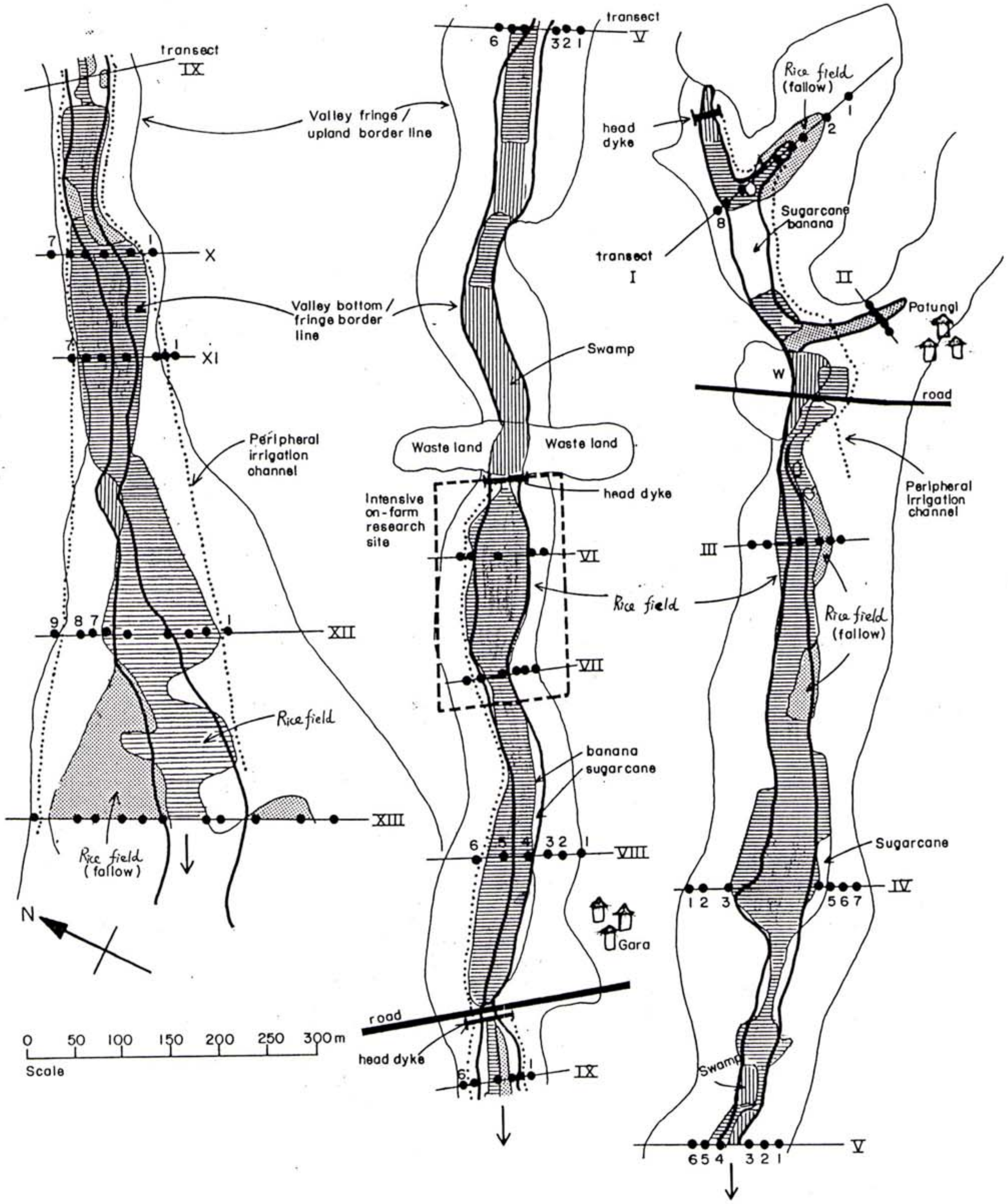


Figure 3. Rice field distribution between in bottomland and in fringe in Gara, November 1986. This map also shows thirteen monitoring transect lines with plastic tubes, which positions are described as black circles with numbering.

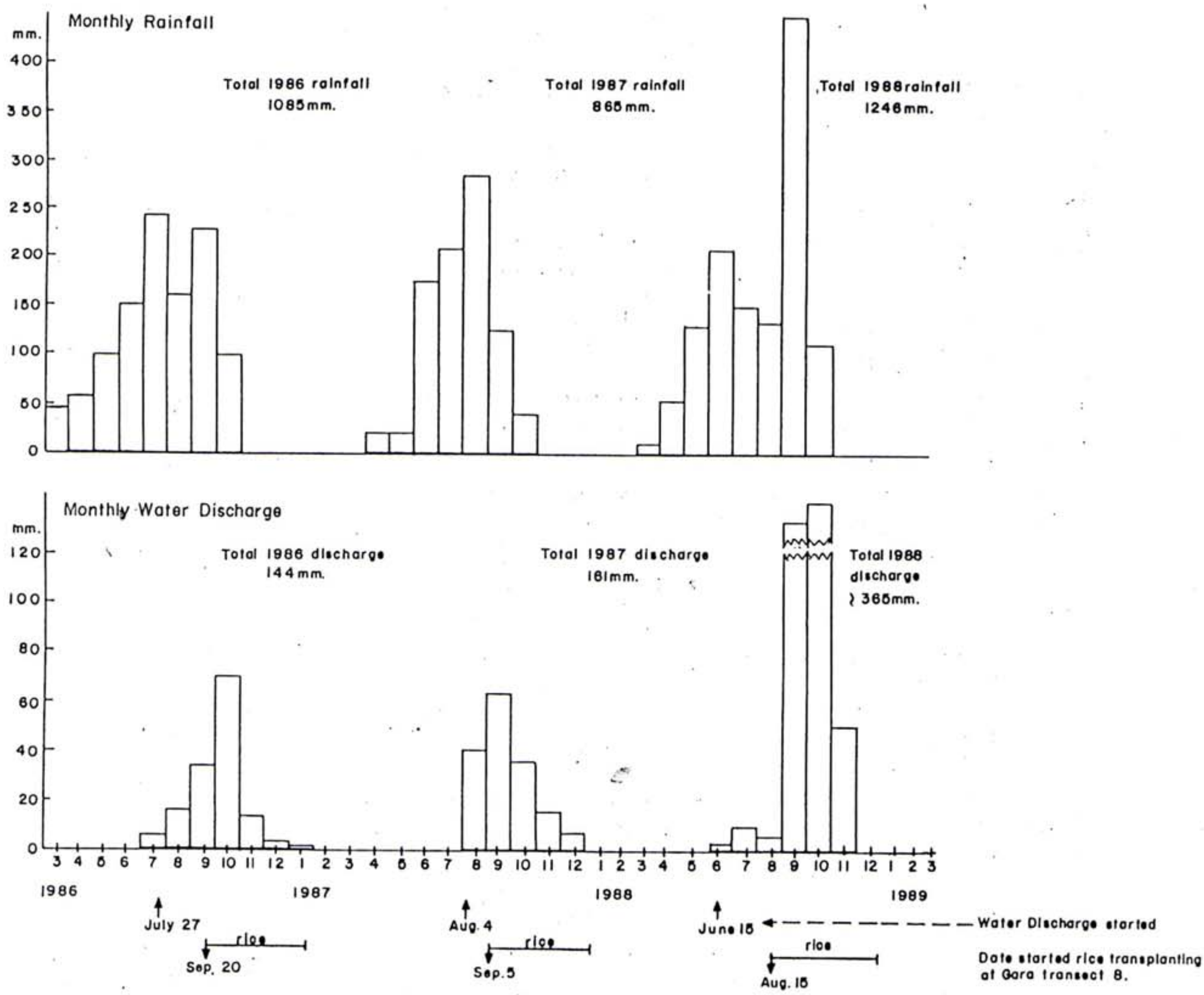


Figure 4. Monthly rainfall-water discharge relationship in Gara valley during March 1986 ~ November 1988.

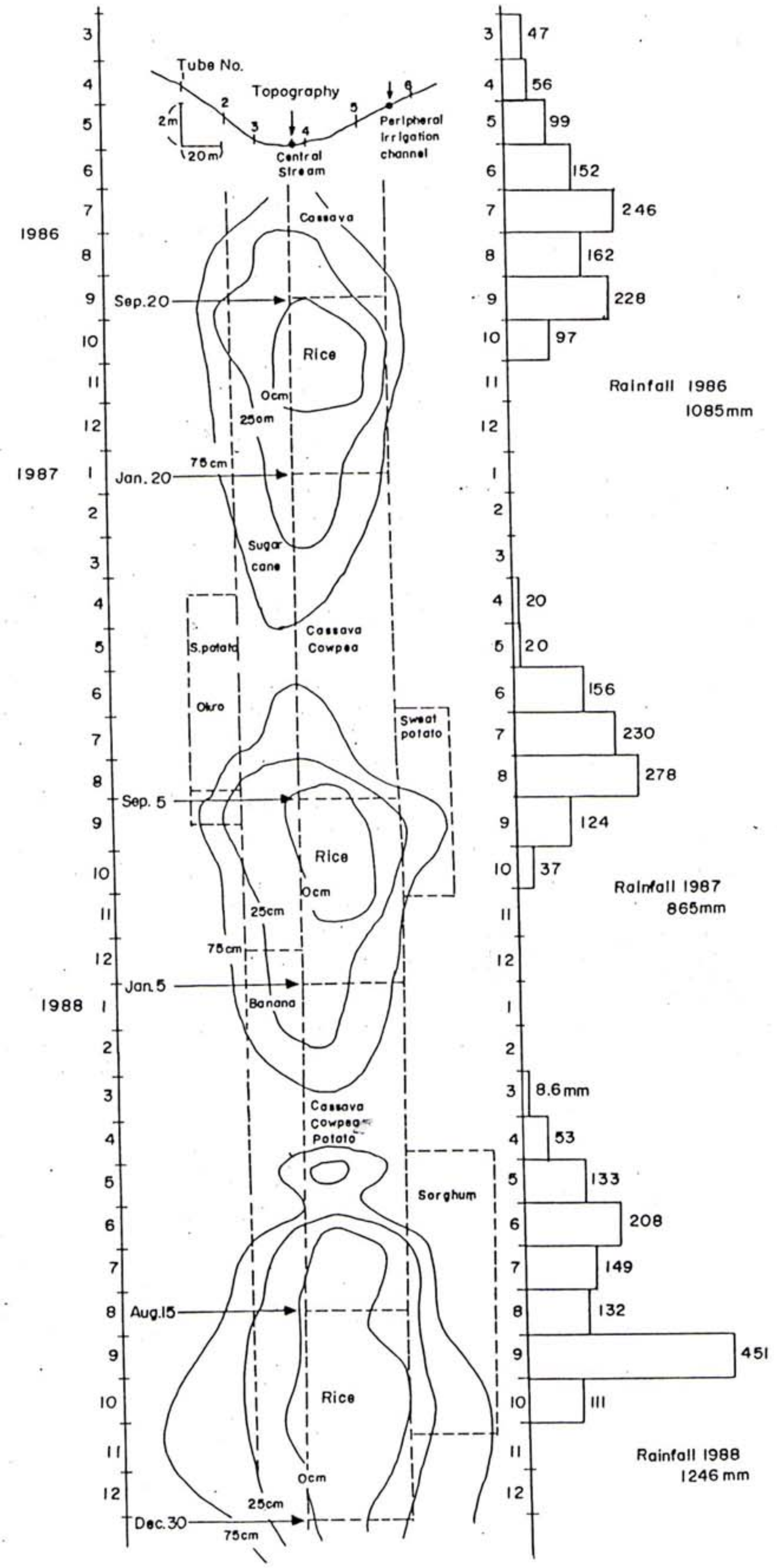


Figure 5. Relation between rainfall pattern, ground water depth in cmn and land use pattern along the transect VIII in Gara valley, the driest part of Drought Prone IVS.

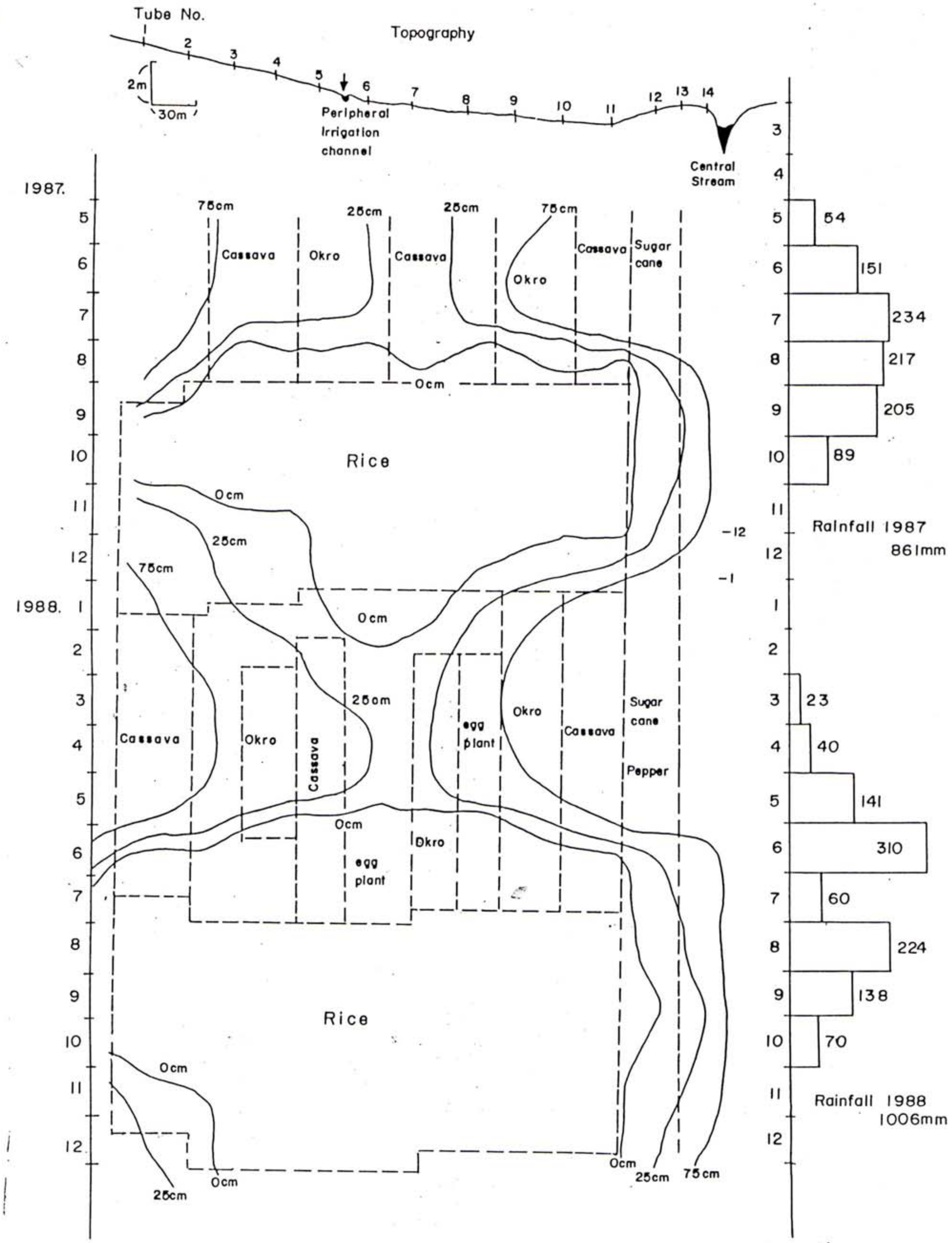


Figure 6. Ground water depth (cm) dynamics and land use pattern along the transect VI in Gadza valley, Fabourable IVS.

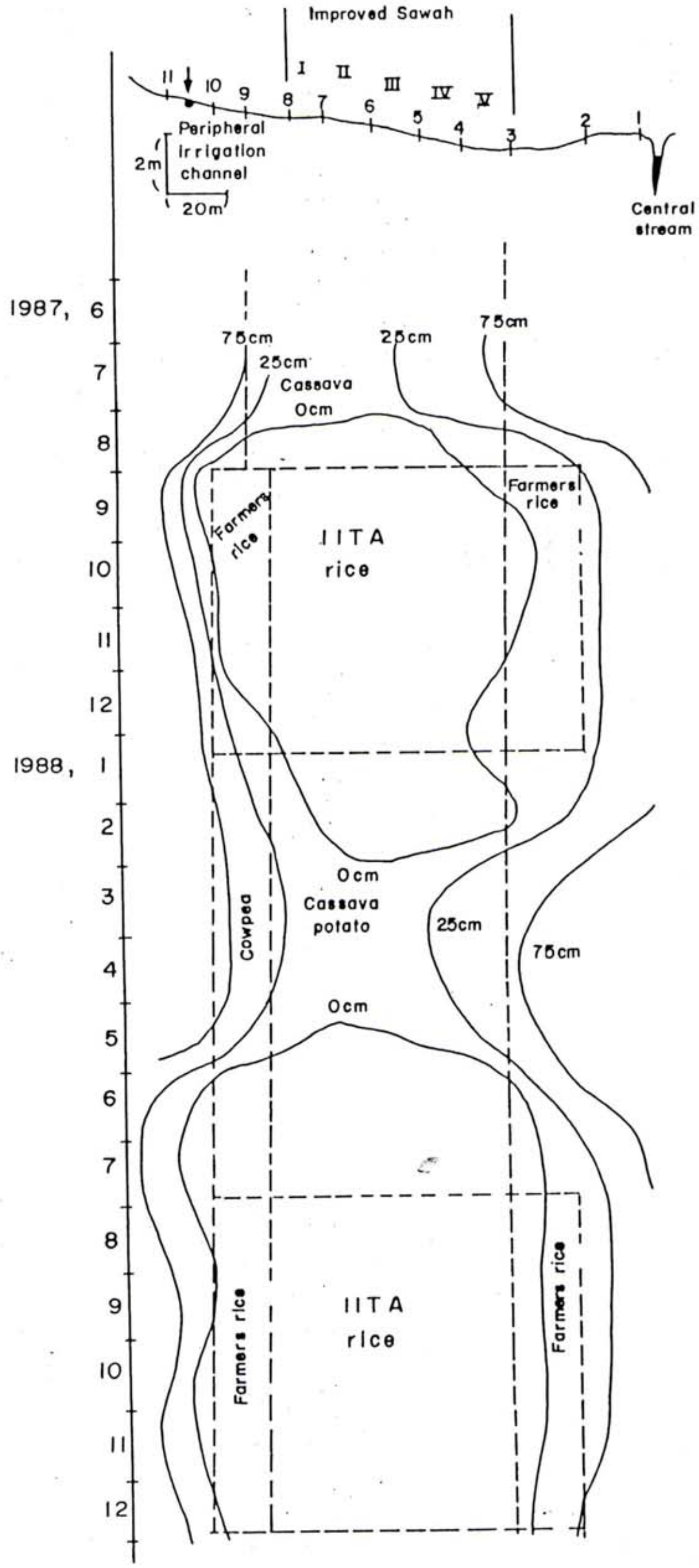


Figure 7. Ground water depth (cm) dynamics and land use pattern along the transect V in Gadza valley, On-farm research site for the effect of the Sawah, Fabourable IVS.